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VARIABILITY IN AGE ESTIMATES IN *SEBASTES* AS A FUNCTION OF METHODOLOGY, DIFFERENT READERS, AND DIFFERENT LABORATORIES [1]

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Age was determined in the fast growing canary rockfish, *Sebastes pinniger,* and the slow growing splitnose rockfish, *S. diploproa,* by different laboratories, techniques, and readers. Variability between agencies depended upon method and species. For *S. pinniger* aged by both laboratories, whole otolith ages were similar, whereas the otolith section ages greatly exceeded those of whole otolith ages. Clear differences were noted for the slower growing *S. diploproa;* whole otolith ageing methods differed between the two laboratories, with much greater ages for larger specimens assigned by one laboratory. These older whole otolith ages showed similarities to the otolith section ages for this species, but still did not reveal the longevity noted with sections. We suggest two areas where improvement in precision of age determination is necessary. First, a consensus on ageing methodology (whole versus sectioned or broken and burned otoliths) is necessary to allow meaningful comparisons between readers. Secondly, mechanisms to allow comparisons between agencies or laboratories are necessary to provide ages which are, at the least, consistent, for use by fisheries managers.

INTRODUCTION

Using otoliths to define annuli and estimate age in fishes is difficult for several reasons. For fast growing species with clear otoliths, a consensus of different readers on age may be obtained, but for longer-lived species, age determination becomes more difficult and subjective (Williams and Bedford 1974, Maraldo and MacCrimmon 1978). The genus *Sebastes* is characterized by species with a great range of longevity, from maximum ages of about 4 to 5 years in *S. emphaeus* (Moulton 1975) to in excess of 80 years in several deeper living species (Beamish 1979*b*; Bennett, Boehlert, and Turekian 1982). In the longer-lived *S. marinus* and *S. mentella,* Sandeman (1961) noted only 9% agreement between readers; as expected, variability between readers increased with increasing age.

Different methods may also produce different results; ageing of *Sebastes* spp. has been conducted with scales (Phillips 1964), whole otoliths (Westrheim 1973, Boehlert 1980), and otolith sections (Beamish 1979*b*). Westrheim and Harling (1973) compared whole otolith versus scale methods for *S. alutus* and noted older ages from otoliths. Bias between readers in the same laboratory, using the same methods, is likely to be less than between agencies or laboratories (Kimura, Mandapat, and Oxford 1979). If, as on the Pacific coast, several agencies routinely age the same species, problems may arise for management in interpretation of the appropriate ages to use.

Whole otoliths are commonly used by management agencies in assessing age structure of a population. Several studies have indicated that a certain amount

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of bias is introduced with this method, especially where older individuals of the species are concerned. Growth of an otolith is a function of age as well as length of the fish. The otolith increases in length up to a given size of fish, after which it ceases to increase in length or width but continues to increase in thickness with age (Blacker 1974, Templeman and Squire 1956). This thickening occurs on the internal surface of the otolith, particularly in slow-growing, long-lived species. Relying solely on whole, surface ageing of the otolith's external surface will therefore neglect this cap of additional material. Certain investigators have found that using a section from an otolith reveals these internal banding patterns and suggest maximum ages which are double or even triple those estimated with whole otoliths (Sandeman 1961, Beamish 1979*a* and 1979*b*); that these older ages represent true ages has been demonstrated for *Sebastes diploproa* using natural radionuclides in otoliths by Bennett *et al.* (1982). Because management agencies are currently reassessing ageing techniques for rockfishes, a comparison of some of the alternative ageing methods and the variability within and between methods is desirable. In the present study we investigate deviations in estimated age of *S. diploproa* and *S. pinniger* as a function of different readers, different laboratories, and different methodologies.

MATERIALS AND METHODS

Sebastes diploproa and *S. pinniger* were sampled at depths from 32 to 205 fm by the chartered vessels F/V PAT SAN MARIE and F/V MARY LOU during the 1980 West Coast Groundfish Survey conducted by the Northwest and Alaska Fisheries Center, National Marine Fisheries Service. Gear, sampling techniques, and shipboard methods generally followed Gunderson and Sample (1980).

Sagittal otoliths were collected from fish captured in all hauls until sufficient numbers of specimens in specified length categories were obtained; very large and very small individuals thus represented a higher proportion in our sample than in the population. Specimens were numbered consecutively, as taken, within sexes. Vessel, leg, haul, sex, and fork length (to the nearest 0.1 cm) were recorded for each specimen. Additional information on each haul included latitude, longitude, and bottom depth. Both otoliths were removed, cleaned, and stored in individual, labelled vials containing 50% ethanol.

General information on otolith morphology and whole otolith ageing methodology in *Sebastes* is described in detail by Kimura *et al.* (1979). Whole otoliths for both species in our study were read with a dissecting microscope at 10x under reflected light. Otoliths were immersed in water on a black background. Generally, the best area to read was on the exterior surface of the whole otolith, from the focus to the dorsal edge. With fish older than approximately 12 yrs, a prominant annulus was followed to the posterio-dorsal or posterior region, where subsequent annuli were counted due to compression of annuli in the dorsal area. With older fish, particularly for *S. diploproa,* the whole otolith was rolled or tilted to enumerate annuli on the outer-most projections in the posterior region (Figure 1).

A single whole otolith age was determined for each specimen of *S. diploproa* by Oregon State University (OSU) reader A and *S. pinniger* by OSU reader B. Fish length remained unknown to all otolith readers, as recommended by Williams and Bedford (1974), among others, to minimize bias in otolith reading. A second whole otolith age was assigned approximately ten weeks after the initial age assignments to determine within-reader differences. Further, for *S. diploproa,* whose otoliths are more difficult to read, one additional whole otolith age was determined by OSU reader C for an estimate of between-reader variability within an agency. After these ages were determined the entire sample of each species was sent to a different age reading laboratory (reader D) to establish inter-agency variability in whole otolith ages.

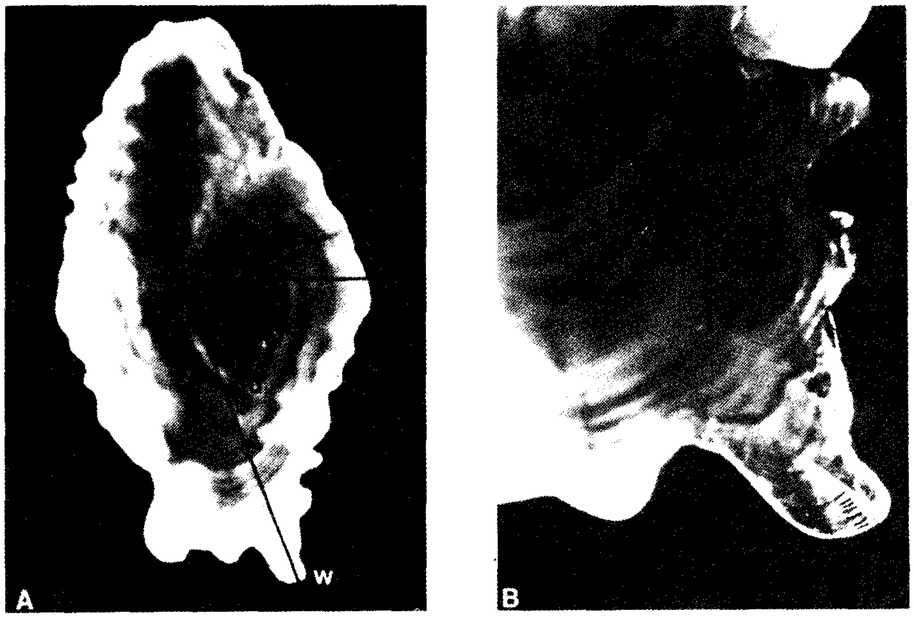

FIGURE 1. A. Exterior surface of the left otolith from a 308 mm FL male *Sebastes diploproa* (8X). The whole otolith age from OSU is 32 yrs. Readings were made from the focus to the dorsal edge (d — axis), continuing along a prominent annulus around to the posterio-dorsal (pd) axis. B. Enlarged portion of the posterior projections (w), showing additional annuli not apparent on the dorsal axis (32X).

The left otoliths of both species were subsequently prepared and sectioned as described by Boehlert (1984). Annuli of specimens younger than approximately 20 yrs were counted on a dissecting microscope using either transmitted or reflected light. The narrow annuli in otoliths from older fish were discerned using transmitted light on a compound microscope at approximately 10x. The ages were determined from the transmitted image on a video screen, for ease of enumeration on older fish. Annuli on the dorso-ventral axis, from the focus to the dorsal edge, are often split on otolith sections, making it difficult to identify the first several true annuli. For this reason, 25 whole left otoliths from *S. pinniger* and 50 from *S. diploproa* were selected, and distance was measured from the focus to accepted annuli (complete rings surrounding the focus) for approximately the first eight years. These measurements were used to identify the location of corresponding annuli on the same axis of the sectioned otolith and showed that our interpretation of annuli was similar between methods for young fish. By following these annuli to the internal, dorsal surface, only a single growth zone was observed, as noted by Sandeman (1961); checks or false annuli found on the whole otolith either disappear or combine on this axis. Section ages were subsequently determined as described in Beamish (1979*b*). Section ages for both species were determined twice for each specimen by OSU reader A, approximately one month apart.

Since true age is not known with certainty for any otolith, initial whole ages determined by reader A for *S. diploproa* and by reader B for *S. pinniger* were considered as "standard age". Initial section ages by reader A in both species were considered "standard". To conduct multiple comparisons of variability, deviations from standard age were defined as shown in Table 1, where group 1 is the difference between independent ages determined by reader A for *S. diploproa* and by reader B for *S. pinniger,* group 2 (for *S. diploproa*) is the difference between standard whole age and that determined by reader C, group 3 compares standard whole otolith age with the age determined by reader D, group 4 is the difference between independent section ages determined by reader A, group 5 is the difference between standard section and standard whole otolith ages, and group 6 is the deviation of reader D whole age from standard section age. Deviations were normally distributed. A one-way analysis of variance (ANOVA) was used to compare these deviations for each species and sex. Multiple range testing was conducted using the Least Significant Difference method (p = 0.05) (Tables 2, 3, 4, 5).

TABLE 1. Identification of the Deviations of Standard Age to Define the Groups in Statistical Comparisons of Deviations.

Group	*Group definition*
1	whole otolith within-reader variation
2	between reader variation (*S. diploproa* only)
3	inter-agency variation
4	section within-reader variation
5	between-method variation
6	between-method-between-agency variation

TABLE 2: Results of One-Way Analysis of Variance and Multiple Range Test Comparing Deviations in Age of *Sebastes Diploproa* Females Determined by Different Readers and Methods. (Groups are defined in text and in Table 1.)

Analysis of Variance

Source	*D.F.*	*Sum of squares*	*Mean squares*	*F*	*P*
Between groups	5	6912.87	1382.57	41.78	<.001
Within groups	1718	56854.99	33.09		
Total	1723	63767.86			

Group	*N*	*Mean*	*Standard deviation*
1	290	0.217	2.018
2	290	−0.728	3.697
3	282	3.206	6.028
4	290	−0.024	2.156
5	290	2.007	6.711
6	282	4.993	9.831

Multiple range test (Least significant difference, P = .05)

Group 2	Group 4	Group 1	Group 5	Group 3	Group 6

TABLE 3: Results of One-Way Analysis of Variance and Multiple Range Test Comparing Deviations of Age in *Sebastes Diploproa* Males Determined by Different Readers and Methods. (Groups are defined in text and in Table 1.)

Analysis of Variance

Source	*D.F.*	*Sum of squares*	*Mean squares*	*F*	*P*
Between groups	5	7784.99	1557.00	36.97	< .001
Within groups	1466	61733.50	42.11		
Total	1471	69518.49			

Group	*N*	*Mean*	*Standard deviation*
1	246	−0.138	1.907
2	246	−0.537	2.669
3	244	2.598	4.972
4	246	0.126	2.445
5	246	3.427	8.595
6	244	5.865	11.746

Multiple range test (Least significant difference, P = .05)

Group 2 Group 1 Group 4 Group 3 Group 5 Group 6

TABLE 4: Results of One-Way Analysis of Variance and Multiple Range Test Comparing Deviations of Age in *Sebastes Pinniger* Females Determined by Different Readers and Methods. (Groups are defined in text and in Table 1.)

Analysis of Variance

Source	*D.F.*	*Sum of squares*	*Mean squares*	*F*	*P*
Between groups	4	1345.59	336.40	46.72	< .001
Within groups	600	4322.49	7.20		
Total	604	5668.08			

Group	*N*	*Mean*	*Standard deviation*
1	121	−0.050	0.717
3	121	1.413	1.838
4	121	0.017	3.152
5	121	2.455	3.209
6	121	3.868	3.449

Multiple range test (Least significant difference, P = .05)

Group 1 Group 4 Group 3 Group 5 Group 6

RESULTS

Sebastes diploproa

The sample of *S. diploproa* otoliths was comprised of 290 female and 246 male specimens. This sample was representative of the age, length, and latitudinal distribution of otoliths described in Boehlert (1984). Standard whole otolith ages ranged from < 1 to 56 yrs for female and 1 to 40 yrs for males. Length frequencies and corresponding age distributions resulting from the various sources of age estimation were tabulated (Table 6). Females were generally more abundant in the large size categories. Mean ages-at-length, both for the females and males, showed distinct differences when comparing whole otolith age estimates from different laboratories. Mean OSU ages were consistently lower than the other agency for the smaller, younger fish and were higher for those older and larger fishes (Table 6).

TABLE 5: Results of One-Way Analysis of Variance and Multiple Range Test Comparing Deviations of Age in *Sebastes Pinniger* Males Determined by Different Readers and Methods. (Groups are defined in text and in Table 1.)

Analysis of Variance

Source	*D.F.*	*Sum of squares*	*Mean squares*	*F*	*P*
Between groups	4	8779.49	2194.87	101.66	<.001
Within groups	850	18350.47	21.59		
Total	854	27129.96			

Group	*N*	*Mean*	*Standard deviation*
1	171	−0.029	0.747
3	171	−0.310	2.812
4	171	0.836	3.665
5	171	6.813	7.065
6	171	6.503	6.011

Group 3 Group 1 Group 1 Group 4 Group 6 Group 5

Reader variability in all comparisons generally increased with increasing fish length (and therefore age), and was greatest for older, larger females. The mean deviation in whole otolith ages between agencies as a function of whole standard age for both male and female *S. diploproa* (Figure 2) was much greater than either within or between reader differences within one laboratory. Up to age 10 for both sexes, OSU ages were more conservative than those of the other laboratory, resulting in negative deviations. After age 10, OSU whole ages were increasingly greater, up to a mean maximum deviation of about 30 yrs for the oldest females and 19 yrs for males. The negative deviations at younger ages could result from different interpretations of assumed annuli; OSU readers identified only complete rings as annuli, as compared with false annuli or checks, for the first several years of growth, although the first growth bands are admittedly difficult to interpret. The deviations at older ages are due to the inclusion of annuli on the posterio-dorsal projections of the otolith in the OSU age estimates (Figure 1).

Otolith section ages for *S. diploproa* were generally greater than whole otolith ages. Within-reader deviations for otolith section ages were similar to within and between-reader whole age deviations. Deviations were great when comparing section and whole ages. For both males and females, the mean deviations of whole from section ages at OSU were low for the first 30 yrs and began to diverge after this age (Figure 3). Maximum deviations were greater for males than for females (51 yrs and 29 yrs, respectively). Females grow faster than males and their otoliths are clearer. Annuli are easier to discern for older females on the surface of the whole otolith. The deviations of whole age from section age are therefore smaller in females. Moreover, from whole otolith estimates, females appear to be older than males, whereas maximum ages estimated from sectioned otoliths reveal an opposite trend (66 yrs for females and 74 yrs for males).

Inter-agency differences between standard OSU section age and whole age from another laboratory as a function of standard section age (Figure 4) showed a pattern similar to that for section-whole deviations within an agency, with a few important exceptions. Mean deviations at ages greater than 10 yrs are greater in the inter-agency comparison and are negative at ages less than 10 yrs. This further emphasizes the difference in ageing criteria used between laboratories. In addition, the deviations diverge from zero at a much lower age; that is, divergence is at 10 yrs for inter-agency and 30 yrs for within-agency comparisons, reflecting the older whole otolith ages determined by OSU.

Sebastes pinniger

This study utilized 121 female and 171 male *S. pinniger* otoliths. As with *S. diploproa*, females were more abundant in the largest size categories (Table 7), apparently due to their faster growth rate (Boehlert 1980, Boehlert and Kappenman 1980). Standard whole ages ranged from 2 to 22 yrs for females and 2 to 25 yrs for males. Mean ages-at-length were generally higher for OSU estimates when compared with the other agency (Table 7).

Otoliths of *S. pinniger* are generally clearer, easier to read, and this species does not reach the ages attained by *S. diploproa*. As expected, mean interagency differences in whole otolith ages were minimal when compared with those of the more difficult to read *S. diploproa* otoliths. Moreover, although section ages were generally greater than whole ages, the magnitude of this deviation was not as great as that observed for *S. diploproa*. This reflects the greater clarity and ease in surface reading of *S. pinniger* otoliths (Figure 5).

Mean within-reader differences were similar in both whole and section age comparisons. Inter-agency differences between OSU standard section age and whole age from the laboratory were similar to within-agency differences of the same comparison; this results from closer estimates of whole ages between agencies. Considering this comparison (between methods), deviations were high but less than those for *S. diploproa*. Maximum between-method deviations, from OSU as well as the other laboratory, were higher for the slower growing, longer-lived males, as observed for *S. diploproa*.

One-way analyses of variance demonstrate significant differences between the sources of deviations in age for both males and females of both species of *Sebastes* (Tables 2,3,4,5). Multiple range testing suggests that mean within-agency sources of deviation for *S. diploproa* (including within-reader for both whole and section ages and between-reader) are similar and significantly less than inter-agency deviations. Consequently, precision in age determination can be high among readers within one laboratory, but can decrease greatly when comparing ages between laboratories. These results also suggest that precision is highly dependent upon the method used in age determination, with comparisons of ages derived through different methods by different laboratories resulting in the greatest deviations.

TABLE 6. Mean Ages-at-Length for Different Readers and Methods of Age Determination in *Sebastes diploproa*.

A. Female (N=290)

Length (cm)	*N*	*Whole otolith age A1*	*A2*	*C*	*D*	*Otolith section age A1*	*A2*
13	1	2.0	2.0	3.0	4.0	2.0	2.0
14	2	2.0	2.0	2.5	4.5	2.5	2.5
15	4	3.5	3.5	3.5	4.5	3.3	3.3
16	5	3.8	3.2	4.8	5.0	3.4	3.6
17	5	4.4	4.0	5.4	5.2	4.2	4.4
18	7	5.1	4.3	5.7	5.4	5.3	5.1
19	8	5.5	5.4	6.4	5.9	5.6	5.5
20	11	6.2	6.1	7.1	6.0	6.0	6.1
21	15	6.3	6.3	6.9	6.9	6.8	6.3
22	12	6.9	6.6	7.9	7.2	7.6	7.5
23	24	7.4	7.3	8.1	7.3	7.5	7.3
24	19	7.4	6.9	7.7	7.3	7.5	7.7
25	13	8.3	8.2	9.5	8.1	10.8	10.5
26	25	9.2	9.4	10.3	9.0	9.6	9.1
27	23	9.4	10.1	10.1	9.2	9.3	9.3
28	10	12.3	11.6	12.0	11.1	11.4	11.3
29	16	16.6	16.3	16.9	12.6	17.3	17.6
30	17	23.1	23.4	22.1	15.6	22.9	23.2
31	15	23.5	25.1	25.3	17.0	25.7	26.1
32	8	28.1	30.0	32.0	21.5	30.4	31.3
33	11	30.1	30.2	33.2	20.1	39.6	40.2
34	9	32.9	36.8	36.7	22.6	48.9	48.3
35	7	39.1	39.0	34.9	23.5	42.9	40.7
36	15	38.3	39.1	38.7	22.2	48.9	49.6
37	7	38.1	37.0	34.9	24.7	40.1	42.0
38	1	36.0	38.0	48.0	18.0	62.0	63.0

B. Male (N=246)

Length (cm)	*N*	*Whole otolith age A1*	*A2*	*C*	*D*	*Otolith section age A1*	*A2*
9	1	1.0	1.0	1.0	3.0	1.0	1.0
11	1	3.0	3.0	3.0	4.0	4.0	4.0
12	1	1.0	1.0	1.0	3.0	1.0	1.0
13	1	1.0	1.0	1.0	3.0	1.0	1.0
14	2	3.5	3.5	4.0	5.0	3.5	1.5
15	5	4.0	2.8	4.2	4.8	4.2	5.6
16	3	4.0	4.0	3.7	4.7	4.0	4.0
17	3	5.0	4.7	5.7	5.3	6.0	6.0
18	8	5.0	4.9	5.6	6.4	5.9	5.5
19	7	5.3	5.0	5.9	6.0	5.4	5.7
20	11	5.5	5.4	6.1	6.1	5.7	5.8
21	16	7.0	6.7	7.0	6.9	6.9	6.9
22	23	7.2	7.1	7.6	7.2	7.3	7.6
23	22	7.7	7.6	8.2	7.4	7.9	8.0
24	16	8.9	8.4	9.1	8.2	9.1	8.9
25	13	8.4	8.4	9.4	9.4	8.7	8.9
26	24	9.6	9.1	9.8	10.0	9.6	9.6
27	13	14.2	13.6	14.2	10.8	14.5	14.9
28	13	19.5	18.4	19.5	13.9	23.4	20.5
29	17	26.7	27.4	27.4	19.1	32.6	34.1
30	15	26.1	26.5	28.9	18.3	33.1	31.3
31	12	29.0	28.9	28.1	16.9	43.3	43.1
32	14	30.2	31.4	31.2	20.1	49.1	48.2
33	3	25.7	25.7	29.7	14.0	47.3	46.7
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36	1	32.0	30.0	33.0	22.0	68.0	69.0

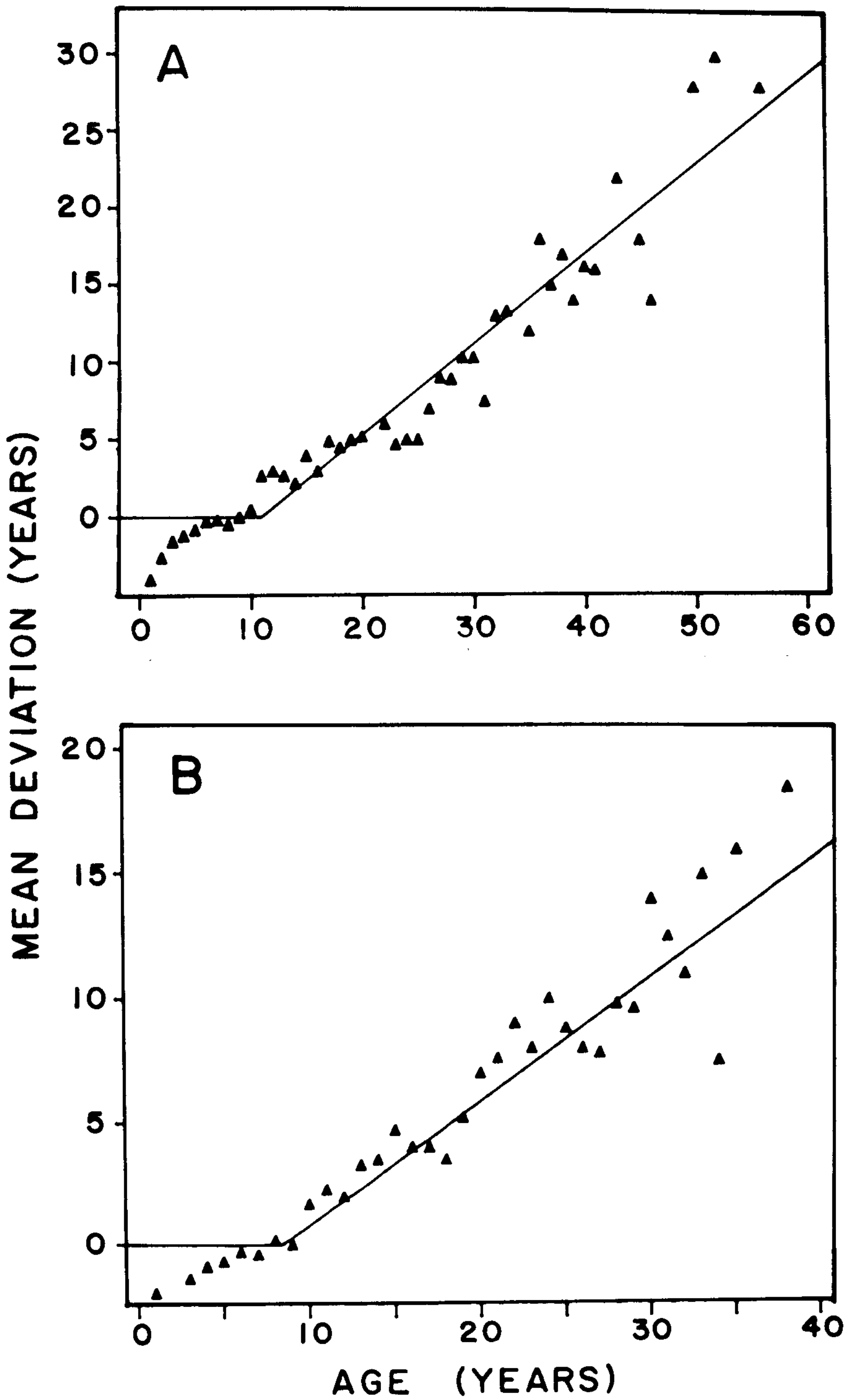

FIGURE 2. Mean deviations in whole otolith ages between agencies for splitnose rockfish, *Sebastes diploproa*. A. Females (N = 290). B. Males (N = 246).

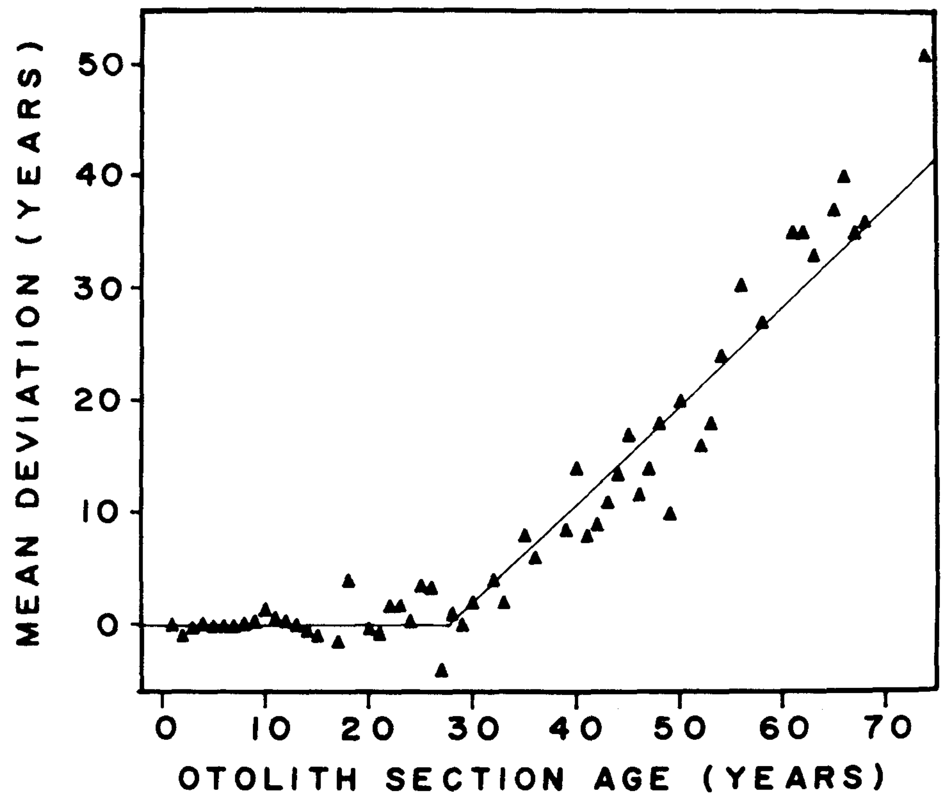

FIGURE 3. Mean deviation of OSU whole otolith age from otolith section age for male *Sebastes diploproa* (N = 246).

For *S. pinniger,* multiple range testing demonstrated similar trends, with deviations in age being greatest when comparing methods both between and within agencies. Inter-agency deviations are relatively low, however, when comparing whole ages from these clear, easy-to-read otoliths.

DISCUSSION

This study does not conclude that assigned ages are accurate, since age validation is beyond the scope of this study. It does suggest that age determination using whole otoliths will not adequately represent the age of most *S. diploproa* beyond 30 yrs and *S. pinniger* beyond age 10 yrs. Section ages seem to more accurately define the age composition of a population, particularly in the case of longer-lived species with difficult-to-read otoliths (Bennett *et al.* 1982). It would therefore be beneficial to examine otoliths from other species of rockfish to determine at what age, if any, it becomes necessary to section the otolith to estimate the true age of the fish. A method which provides results similar to sectioning is the break and burn technique, as described by Chilton and Beamish (1982). This technique, which also involves examination of an otolith cross section, may be more amenable to production-type age determination than the sectioning methods used in the present study. In the genus *Sebastes,* however, it is apparent that these greater ages exist in a wide variety of species (Shaw and Archibald 1981).

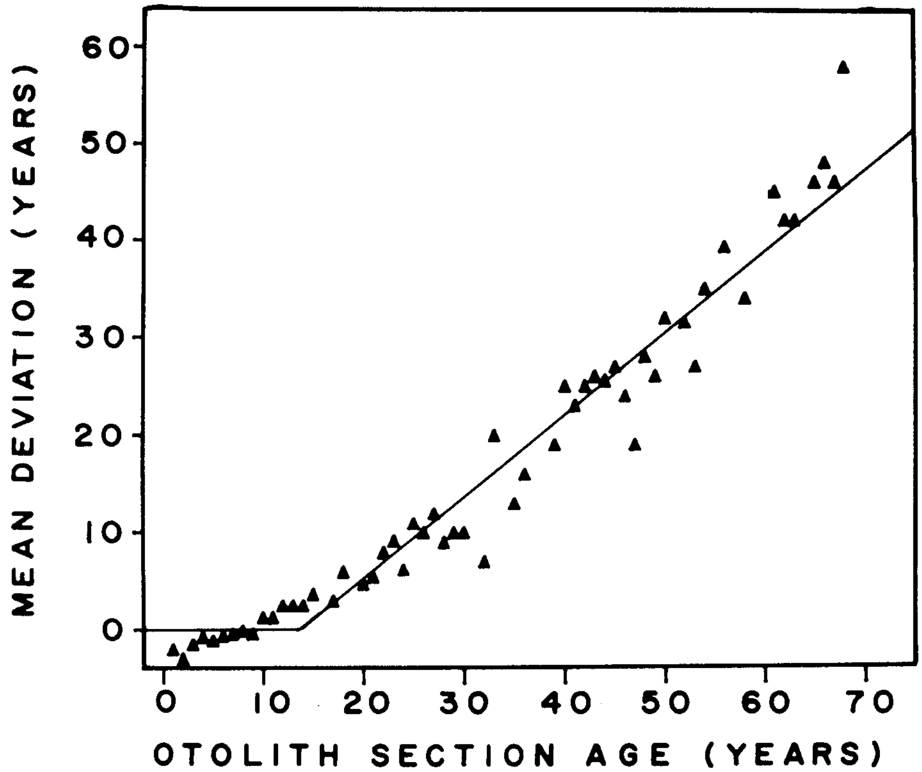

FIGURE 4. Differences between otolith section ages and whole otolith ages from another agency for male *Sebastes diploproa* (N = 246).

It is clear from our results that an important part of the populations of both species is significantly underaged using the whole otolith technique, particularly by the other laboratory (Figures 3,4,5). An important point to note from these data is the fact that the deviations for males are generally greater than those for females. Female *Sebastes* grow faster than males for most species (Boehlert and Kappenman 1980, Westrheim and Harling 1975) and are therefore characterized by otoliths which have broader, clearer annuli on whole otoliths to a greater age. Thus, the age at which the otolith growth occurs only as "caps" on the internal surface will be greater for females. Using whole otoliths for age determination, the females will appear to be older than the males whereas the opposite is actually true based upon section age (Tables 6 and 7). The systematic bias which is introduced by using whole otolith ages is therefore compounded by differences in the error of longevity estimates for males and females.

These older fish represent an important part of the population which should not be ignored. Hirschhorn (1974) argued that excluding older, difficult-to-age individuals from growth analysis for the population can have detrimental effects upon estimates of von Bertalanffy parameters. For production modelling or stock analysis purposes, unbiased errors in age determination, particularly for older segments of the population, will have little effect, whereas systematic bias in

TABLE 7. Mean Ages-at-Length For Different Readers and Methods of Age Determination in *Sebastes pinniger*.

A. Female (N=121)

Length (cm)	N	Whole otolith age B1	Whole otolith age B2	Whole otolith age D	Otolith section age A1	Otolith section age A2
15	1	2.0	2.0	2.0	2.0	3.0
31	1	5.0	5.0	4.0	7.0	7.0
32	2	5.5	5.0	3.5	7.0	7.0
33	1	4.0	4.0	3.0	3.0	4.0
36	1	9.0	9.0	8.0	13.0	12.0
37	1	7.0	7.0	6.0	8.0	8.0
38	3	7.0	7.3	6.3	8.3	10.7
39	1	6.0	6.0	5.0	6.0	6.0
41	3	8.0	8.0	7.7	10.3	10.3
42	2	9.5	9.5	8.0	10.5	10.5
43	2	8.0	8.0	7.5	11.0	11.0
44	1	9.0	9.0	8.0	10.0	9.0
45	2	11.0	11.0	10.0	12.0	13.5
46	5	11.0	11.4	9.0	11.4	11.8
47	4	11.0	11.0	8.0	12.5	10.5
48	7	11.9	12.0	11.1	12.7	13.0
49	8	11.8	12.0	10.5	12.3	13.4
50	5	11.2	11.4	10.8	12.6	16.4
51	10	12.8	12.7	11.2	15.6	14.9
52	9	13.1	13.1	10.7	14.9	13.9
53	18	13.6	13.6	12.2	16.8	16.6
54	6	13.5	13.8	12.8	16.0	15.8
55	8	15.4	15.3	14.1	18.5	17.6
56	9	15.7	15.2	13.8	19.9	19.6
57	5	14.6	14.8	12.6	19.4	19.6
58	2	16.0	16.5	15.5	17.0	15.5
59	1	16.0	16.0	16.0	28.0	27.0
60	1	17.0	16.0	11.0	15.0	26.0
61	2	18.5	20.0	17.0	30.5	26.5

B. Male (N=171)

Length (cm)	N	Whole otolith age B1	Whole otolith age B2	Whole otolith age D	Otolith section age A1	Otolith section age A2
17	1	2.0	2.0	2.0	2.0	3.0
20	1	3.0	3.0	3.0	3.0	3.0
22	1	3.0	3.0	3.0	3.0	4.0
23	1	3.0	3.0	3.0	4.0	5.0
28	1	5.0	5.0	5.0	6.0	6.0
34	2	7.0	7.0	6.5	8.5	8.0
37	2	6.0	6.0	4.0	7.0	8.0
38	1	7.0	7.0	5.0	9.0	8.0
39	1	8.0	8.0	8.0	13.0	10.0
40	5	8.0	8.0	7.8	9.2	9.6
41	2	7.5	7.5	7.0	8.5	12.5
42	4	8.3	8.3	6.5	7.8	9.3
43	4	10.3	10.5	8.0	12.5	14.8
44	4	9.5	9.5	9.5	11.3	13.5
45	4	12.5	12.5	9.8	15.3	18.5
46	7	11.6	11.9	10.9	15.1	16.7
47	16	11.8	11.8	11.4	15.1	15.4
48	9	13.0	12.9	13.2	15.7	16.4
49	13	12.8	13.5	13.8	18.0	18.3
50	25	13.3	13.4	13.7	19.2	20.6
51	14	15.1	15.3	16.2	26.4	27.7
52	18	15.5	15.4	15.8	25.3	25.9
53	17	17.3	17.0	19.5	29.6	29.8
54	7	15.9	16.0	17.9	28.9	29.4
55	4	18.8	18.8	19.5	33.3	30.8
56	2	18.5	18.0	21.5	43.0	50.5
57	4	18.8	18.8	17.8	29.8	29.0
58	1	16.0	15.0	15.0	32.0	25.0

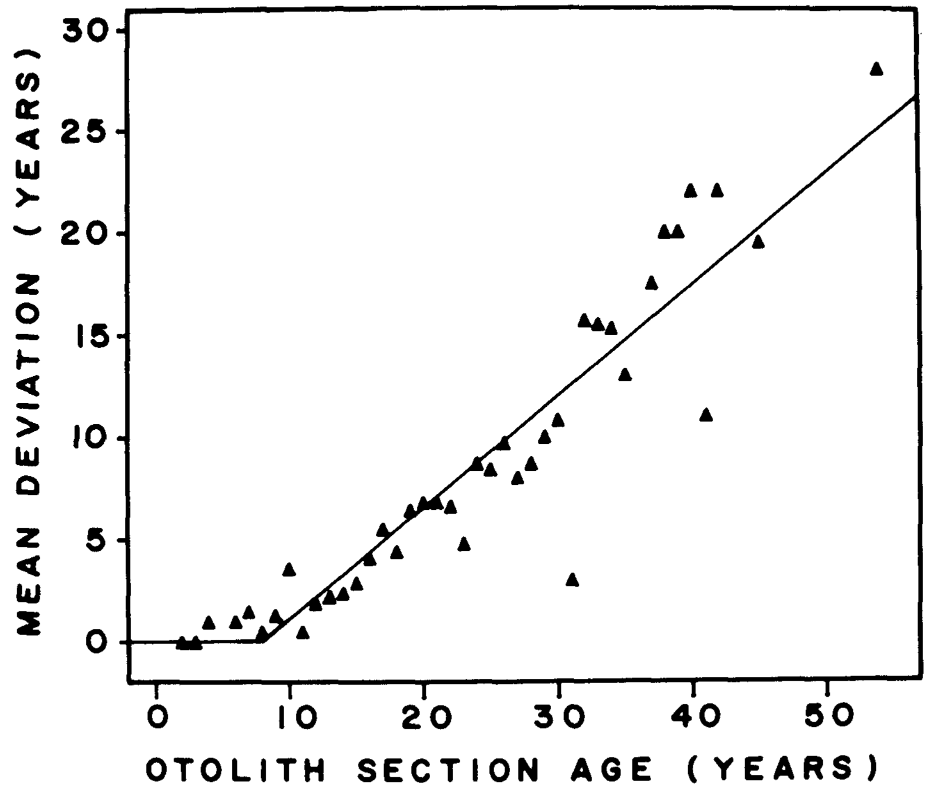

FIGURE 5. Differences between section age and whole otolith age determined by another agency for male *Sebastes pinniger* (N = 171).

ageing may give rise to serious errors (LeCren 1974). Thus, the systematic errors introduced by using ages determined from whole otoliths will negatively affect production models. Calculations of both natural and fishing mortality will clearly be in error, and use of such age data in cohort analysis or virtual population analysis will result in inaccurate cohort strength estimates.

It is difficult to define the causes of the systematic error between agencies. Some error may arise from method alone. Use of different magnifications, for example, may result in different visibility of annuli. Reading otoliths with transmitted versus reflected light, in aqueous media versus dry, or other minor changes in method may result in such systematic differences. Methodological problems will be easiest to solve. Differences in interpretation are more difficult to address. Ages determined within agencies may show high precision and repeatability, but differ significantly from ages at another agency. This suggests that training and frequent cross-checking can solve the problems between agencies.

This study represents an effort to consider the errors inherent in ageing rockfish based upon reader variability, method variability, and agency variability. We concur with Kimura *et al.* (1979), that variability among agencies is greater than that between readers in the same laboratory. We suggest that significant effort be placed upon minimizing variability between agencies. A necessary first step to this goal will be standardization of methods and equipment for ageing each species. Within each species, common interpretation of criteria for defining annuli must be developed. Achieving this goal will initially take a great deal of uniform training and interagency calibration. Continued communication among otolith readers of different agencies, while expensive in time and travel, will ultimately result in more effective fisheries management.

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